New Multilayer Interlayer Creates Al_2O_3 Joints Stable to 1100˚C

A new method of joining ceramics for high-temperature applications has been developed by a research team directed by Andreas M. Glaeser of the Ceramic Science Program in the Center for Advanced Materials. The method can be used to make aluminum oxide ceramic joints that retain useful levels of strength up to 1100°C, far beyond the 600°C limit of standard commercial techniques.

Ceramic materials have a number of desirable properties—strength at elevated temperature, corrosion resistance, high strength to weight ratio, good wear resistance—that make them an attractive choice for high-temperature, high-stress applications such as high-temperature energy conversion and power generation systems. However, the difficulty of shaping ceramics into complex parts has limited their use in these applications. Assembling complex parts by joining simpler components would appear to be a solution to this problem. However, while techniques for joining ceramics to themselves and to metals have been developed, many are only applicable to relatively low temperature applications. Indeed, there is a general lack of brazes for application temperatures above 600°C.

Research into ceramic joining techniques in the Ceramic Science Program has focused on developing methods based on multilayer metallic interlayers designed to lower the required process temperature and bonding pressure (to avoid metal/ceramic reactions that might degrade the microstructure) while maximizing the service temperature. Recently, the MSD team used an interlayer consisting of a thick (125 µm) core layer of niobium surrounded on both sides by a thin (3 µm) layer of copper to join alumina ceramics by brazing at temperatures between 1150°C and 1400°C. By adjusting the processing temperature and bonding pressure, joints with highly reproducible, increased strength could be produced. In these joints, room temperature failure at stresses of 240 MPa ± 20 MPa occurs in the alumina not the joint (see figure). Bend tests performed at up to 1100°C on these optimized joints indicate that significant strength is retained at high temperature with failures, when they occur, again located in the ceramic, not the joint.

Joints were formed with transparent sapphire to allow optical characterization of the interface, and to examine the mechanism of joining. Grain boundary ridges and asperities on the bonding surfaces provide initial points of Al_20_3-Nb contact. It was shown that during processing, copper forms a discrete phase of "islands" through interfacial dewetting that appears to result in direct bonding between the Al_20_3 and niobium over most of the interface. Thus, at temperatures approaching the melting temperature of copper (1083°C), it is the higher melting temperature niobium (m.p. = 2468˚C) that supports the applied load and is responsible for the strength at elevated temperature. Although the mechanism by which the use of copper leads to strengthening is not completely understood, the simplest explanation is that without the copper, which serves as a high diffusivity path for niobium, the development of comparable levels/degrees of Nb-Al_20_3 contact (which creates the bond) would require substantially longer processing times. There is no theory and insufficient experimental data to quantify exactly how much longer more processing would be required, but it is estimated that it would be at least a factor of ten, and possibly a factor of 100 to 1000 greater.

Work with higher purity alumina has suggested that further improvement in joint strength and temperature capability are possible. Samples were tested at temperatures up to 1300˚C, and again instances of failure/deformation that occurs in the ceramic are observed. In addition, the team is developing metal combinations to enable extension of the technique to the preparation of strong, high-temperature joints for other material combinations, for example, joining other ceramics to each other or to metals.

Andreas Glaeser (510.486.7262), Materials Sciences Division (510.486-4755), E. O. Lawrence Berkeley National Laboratory

R. A. Marks, D. R. Chapman, D. T. Danielson, and A. M. Glaeser, "Joining of alumina via copper/niobium/copper interlayers," *Acta. Mater.* **48**, 18-19, 4425-4438, 2000.